Improving real-time rapid intensity forecasts with total lightning data

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Background

- Numerous studies have looked at relationship between lightning and tropical cyclone (TC) intensity & intensity change
  - Intuitive connection: Inner core lightning → deep convective activity → intensification
- Relationship is complicated due to other influences on TC lightning, such as vertical shear, sea surface temperatures, land interactions, etc.
  - E.g., TCs experiencing moderate to strong vertical shear often have increased lightning activity in inner core (DeMaria et al. 2012)
- Lightning-based predictors have been tested in the statistical Rapid Intensification Index through GOES-R Proving Ground
  - Inner core lightning density, r=0-200km, negative coefficient
  - Outer region lightning density, r=200-400km, positive coefficient

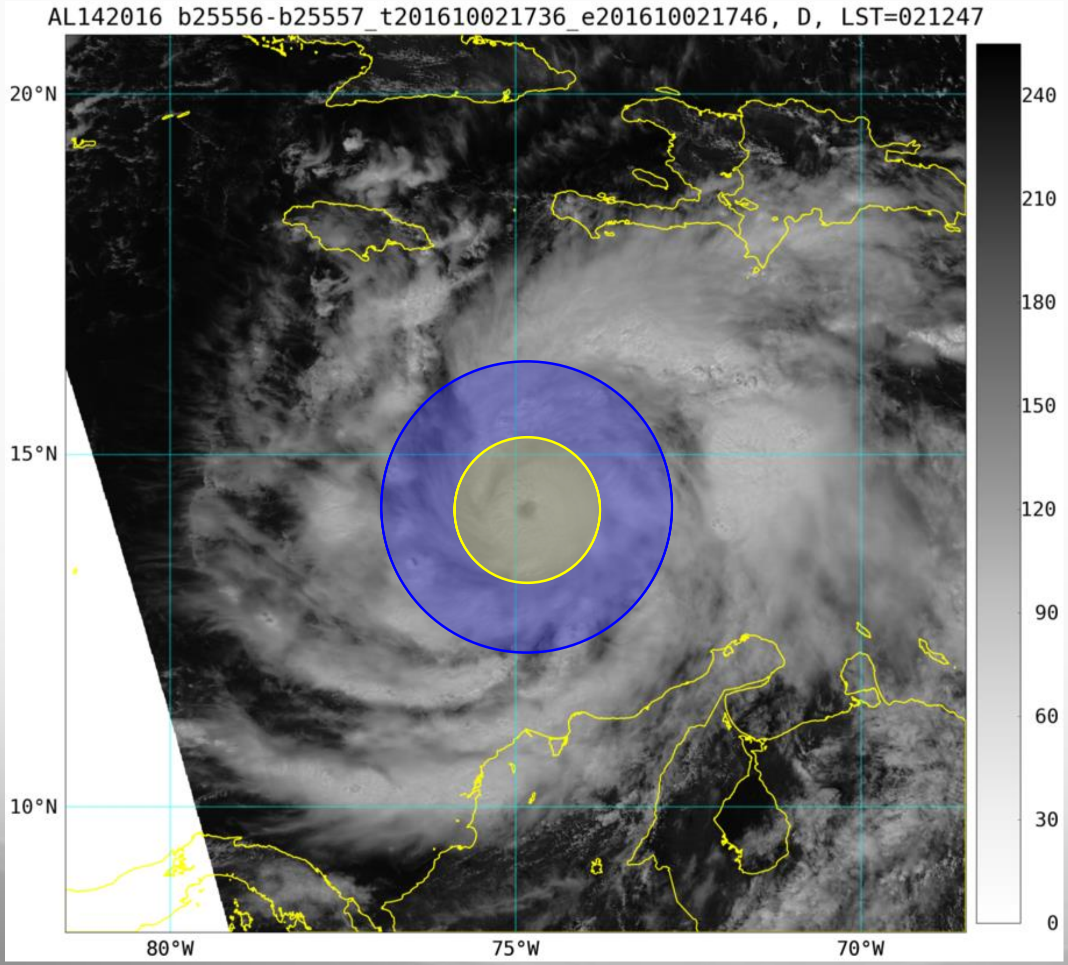
Motivation

- Shortfalls of TC lightning data
  - Ground-based networks have low detection efficiencies over oceans
  - TRMM LIS provides “snapshots” – lacks temporal resolution needed
- With launch of GOES-16, a new source of lightning data will be available via Geostationary Lightning Mapper (GLM)
  - Near-continuous measurement of total lightning over large domain (including TC regions)
  - 70-90% detection rates
- Main goal of this project has been to investigate potential relationships between ***total GLM-proxy*** lightning data and TC intensity change

Data

- Earth Networks Total Lightning Network (ENTLN) flashes
  - Provided by Earth Network, Inc.
  - Global flashes, 2011-2014
- World Wide Lightning Location Network (WWLLN) flashes
  - Global flashes, 2005-2014
  - Provided by University of Washington
- Network detection efficiencies
  - Performance data with respect to TRMM/LIS on 2° resolution western hemisphere grids for both WWLLN and ENTLN (S. Rudlosky)
- Atlantic Best Tracks (ftp.nhc.noaa.gov/atcf/)
  - TC location and intensity every 6 hours
- Storm-centered variables from SHIPS diagnostic files

Storm-relative cylindrical coordinates



For this study, azimuthal average lightning density (flashes km^{-2} year^{-1}) in the inner core and outer regions are examined

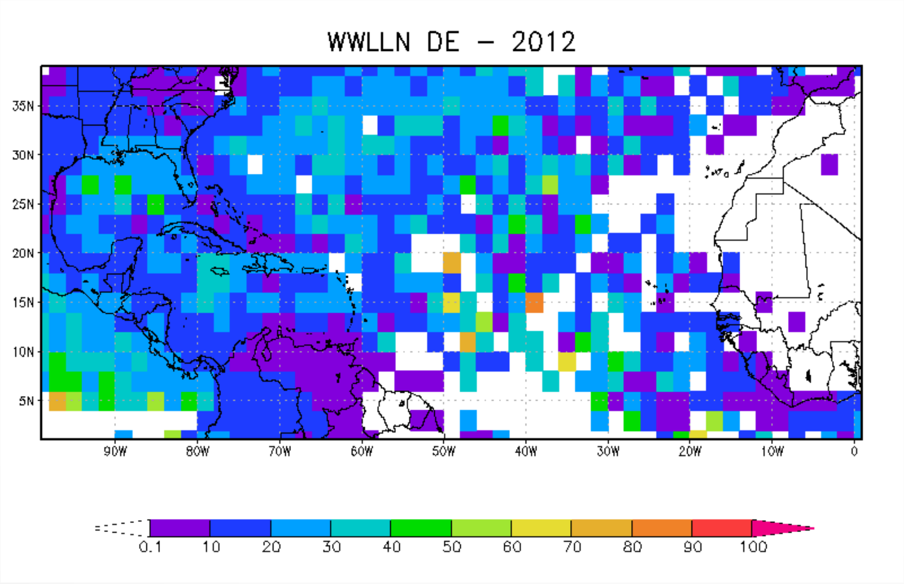
TC center positions are obtained from the HURDAT

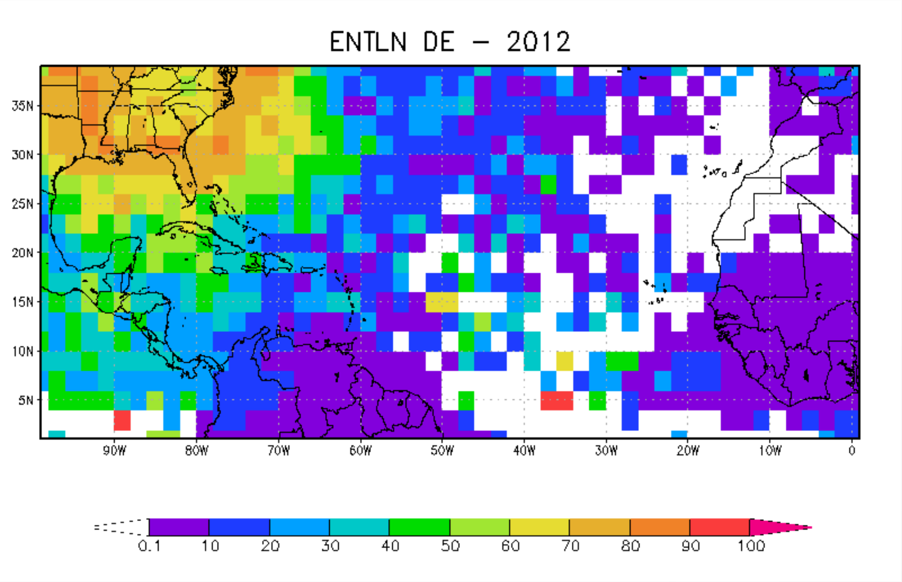
Inner Core → r = 0-200 km

Outer region → r = 200-400 km

Chose radii to be consistent with lightning-based predictors used in statistical rapid intensification index

Detection efficiency





DE ~10-30% throughout domain

Relatively spatially uniform

Previous studies have accounted for temporal variability only (e.g., DeMaria et al. 2012)

DE ~0.1-90% throughout domain

Larger reported IC flash detection

Large spatial variability

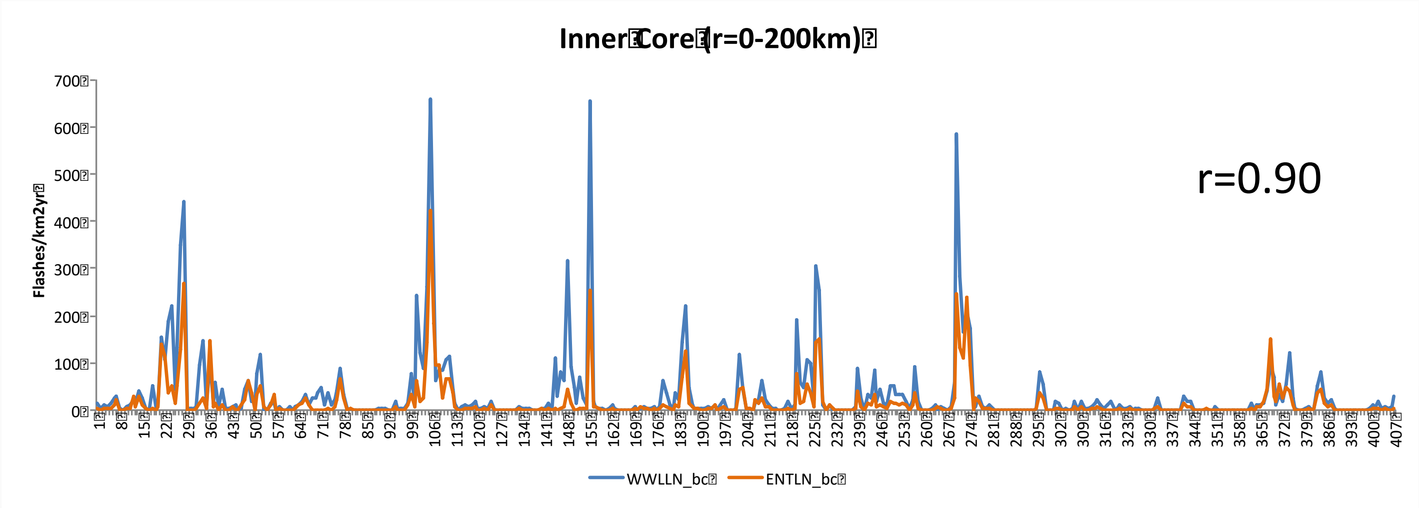
Must account for both spatial and temporal variability in DE

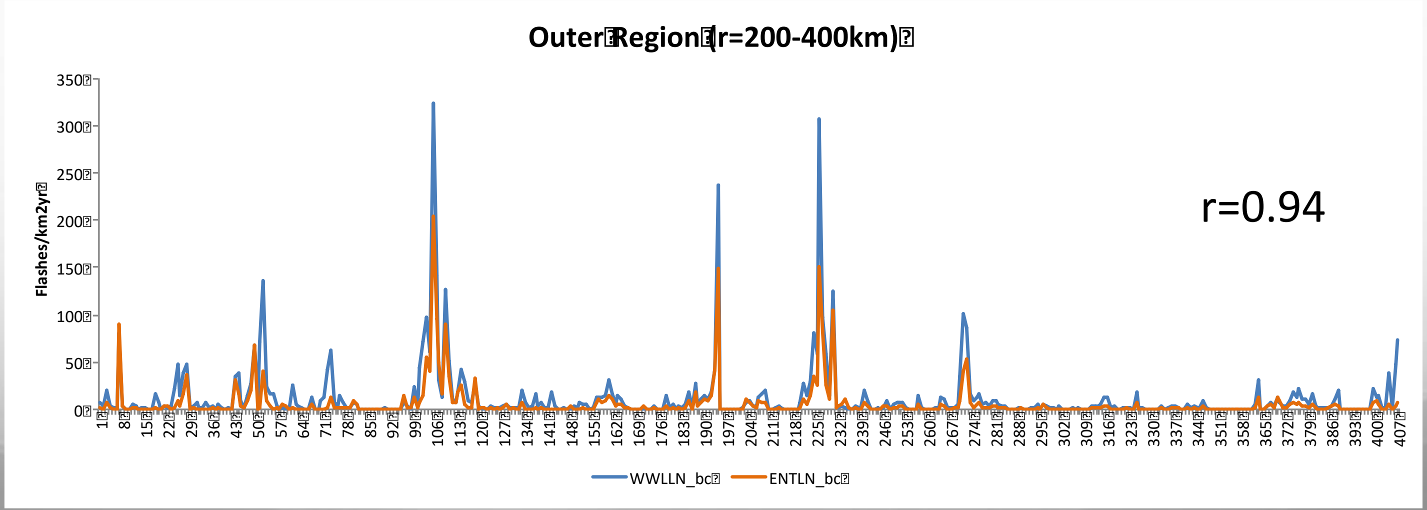
**Detection efficiencies provided by Dr. Scott Rudlosky*

Statistical Comparisons

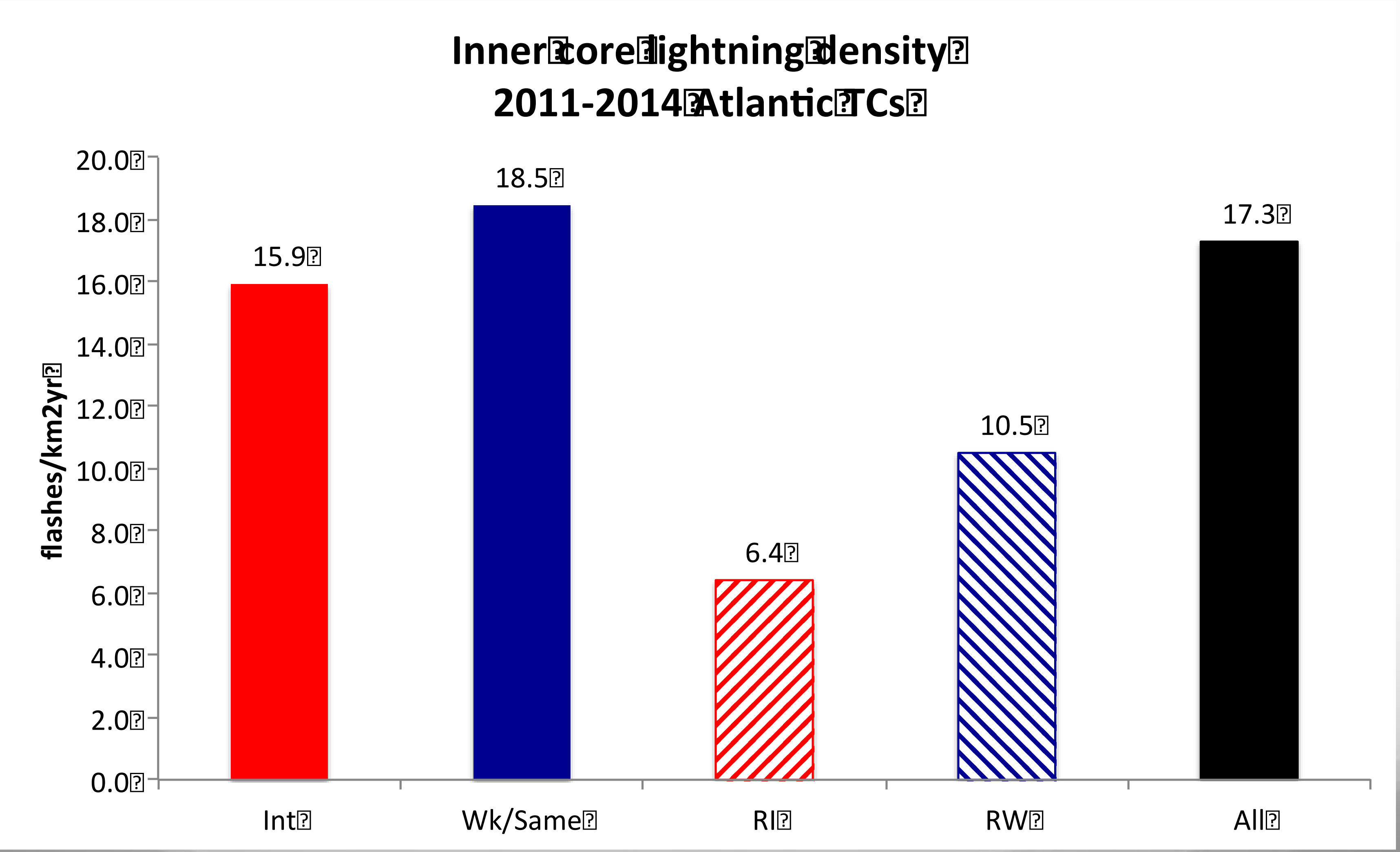
- WWLLN and ENTLN flash counts are expected to be comparable over much of the tropical Atlantic ocean
- Preliminary analyses attempted to apply a temporal bias correction to ENTLN data, as had been used in DeMaria et al. 2012
- Neglecting the spatial variability of ENTLN DE, especially near the U.S. coast, introduced a substantial bias to this previous work
- This study applies a bias correction based on annual DE values, which accounts for both temporal and spatial biases

DE-based bias correction Atlantic TCs, 2011-2012

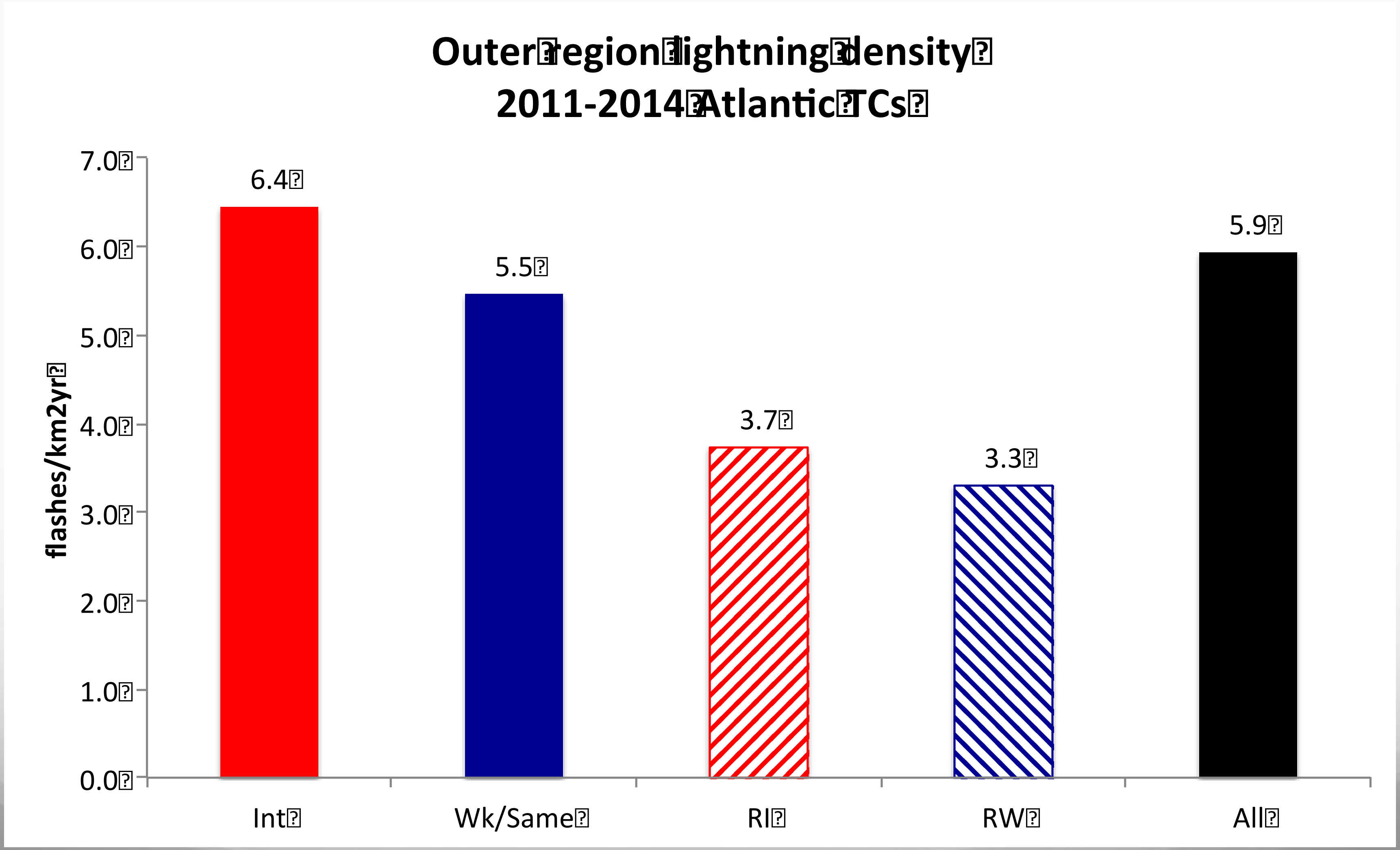




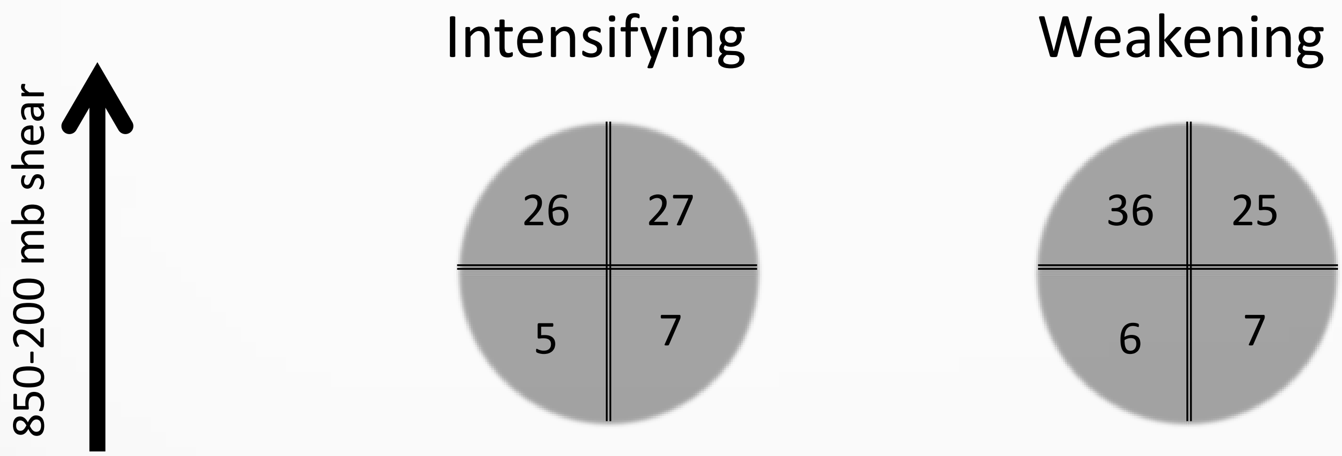
Inner core lightning & intensity change



Outer region lightning & intensity change

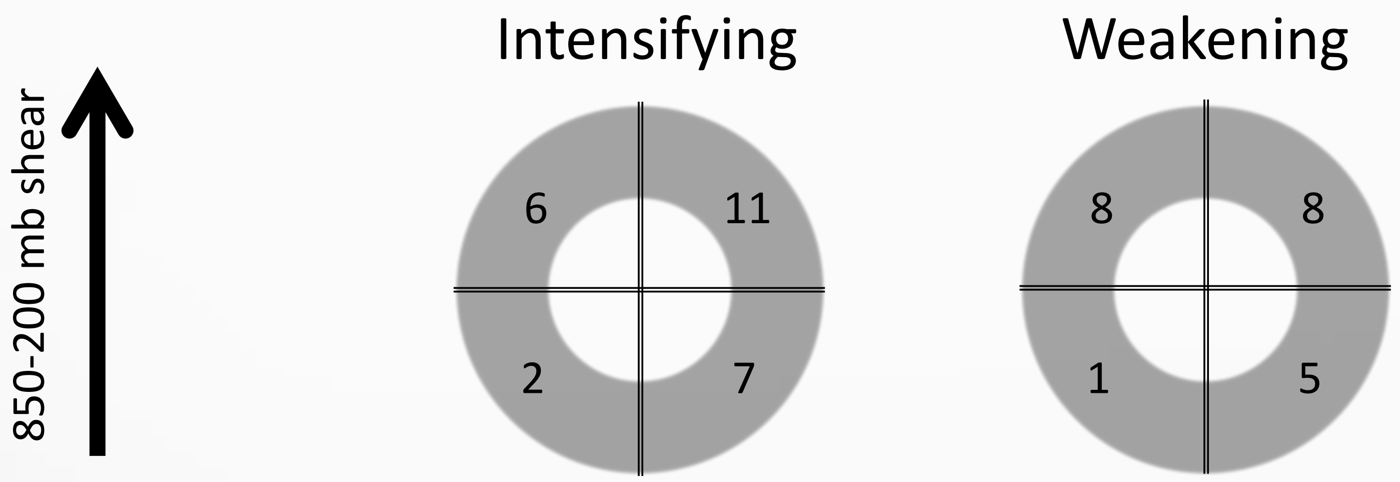


Inner core lightning, shear-relative quadrants



- Lightning activity highest in downshear quadrants
- Lightning enhanced in downshear-left quadrants for weakening TCs
  - Deep convection tends to be focused in the downshear-left quadrant in the presence of significant deep-layer vertical wind shear
  - Vertical shear often leads to weakening

Outer region lightning, shear-relative quadrants



- Lightning activity highest in downshear quadrants for weakening TCs (once again, signal consistent with shear)
- Lightning activity greater in the downshear-right quadrant for intensifying TCs (?)

Rapid Intensification Index (RII)

- Uses subset of SHIPS predictors related to RI
- Input to a discriminant analysis algorithm
- Provides probability of RI (25 kt, 30 kt, 35 kt, 40 kt) in next 24 hr
- Testing inner core and outer region lightning density as predictors (GOES-R PG)

PREDICTOR	DEFINITION
PER	Previous 12-h intensity change (kt)
SHDC	850-200 mb vertical shear (kt)
TBSTDo	Standard deviation of IR brightness temperature
RHLO	850-700 mb relative humidity (%)
POT = MPI-Vmax	Maximum Potential Intensity – Current Intensity (kt)
OHC	Oceanic heat content (kJ cm^{-2})
D200	Upper-level divergence (10**7s^{-1})
PC30	Percentage of GOES pixels colder than -30^{o}C
TWAT	0-600 km avg sym v_T at 850 hPa, NCEP analysis (m/sec *10)

WWLLN vs. ENTLN in the RII

2011-2014 Atlantic TCs

VAR	No Lightning	WWLLN	ENTLN
CONST	7.376	7.062	7.09
POT	0.112	0.172	0.188
SHDC	-0.284	-0.254	-0.234
D200	-0.666	-0.715	-0.753
PER	0.536	0.542	0.554
PC30	-0.13	-0.014	0.008
TBSTDo	-0.468	-0.396	-0.404
OHC	0.595	0.578	0.549
RHLO	-1.086	-1.109	-1.122
TWAT	0.901	0.866	0.874
LM02		-0.327	-0.405
LM24		0.262	0.395
Brier Skill Score	**14.0**	**15.7**	**15.9**

Summary / Future Work

- Given expected similarities between WWLLN and ENTLN over our domain of interest, not surprising our statistical analysis has not yielded any major differences in lightning/TC relationship
- Currently using statistical analysis to identify case studies where ENTLN and WWLLN are significantly different (most likely where ENTLN DE is higher)
- Using downshear left inner core lightning density may improve current lightning-based RII (developing prototype for testing in 2017)
- Can explore with real GLM data soon!

- Many thanks to…
  - World Wide Lightning Location Networks - Univeristy of Washington (http://wwlln.net/)
  - Earth Networks, Inc. (https://www.earthnetworks.com/)
  - Dr. Scott Rudlosky, NOAA/NESDIS/STAR

- References

  - DeMaria, M., R. T. DeMaria, J. A. Knaff, and D. Molenar, 2012: Tropical Cyclone Lightning and Rapid Intensity Change, *Mon. Wea. Rev.*, **140**, 1828-1842.
  - Rudlosky, S.D. and D.T. Shea, 2013: Evaluating WWLLN Performance Relative to TRMM/LIS., *Geophys. Res. Let.*, **40** (10), 2344-2348.
  - Rudlosky, S.D., 2014: Evaluating ENTLN Performance Relative to TRMM/LIS., *J. Operational Meteor.*, **3** (2), 11-20.